DRY TORTUGAS NATIONAL PARK

GEOLOGIC RESOURCE MANAGEMENT ISSUES

SCOPING SUMMARY

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Fort Jefferson and moat at Dry Tortugas National Park. Photograph by Trista L. Thornberry- Ehrlich (Colorado State University).

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Executive Summary

Following a field trip on January 23, 2005, a Geologic Resources Evaluation scoping meeting took place in Homestead, Florida on January 24, 2005. The scoping meeting participants identified the following geologic resource management issues.

1. Coral reef framework rehabilitation and restoration is needed in response to anthropogenic degradation and disease. Vessel groundings are of particular concern.

2. Sea level rise is a concern for all of South Florida. Further research and monitoring is needed to determine how the environments at Dry Tortugas will respond to rising seas.

3. Benthic ecosystems need to be mapped at a large scale in the park using a multidisciplinary approach for resource management.

4. Island geomorphic processes and stability of Fort Jefferson are closely linked. Resource management must understand the nature of the underlying sediments to attempt to stabilize the crumbling fort. Modeling of sediment transport patterns and rates will help to predict shoreline evolution.

5. Groundwater flow dynamics, dictated by the hydrogeologic system, need to be modeled to predict nutrient/contaminant flow paths and to monitor water quality at the park.

6. Recreation and other use (including commercial fishing boats) threaten the reefs and sea grass beds at the Dry Tortugas. Remediation of the anchorage at the park is being considered.

Introduction

Following a daylong field trip on January 23, 2005, the National Park Service held a Geologic Resource Evaluation scoping meeting for Dry Tortugas National Park at the Krome Center in Homestead, Florida on Monday, January 24, 2005. The purpose of the meeting was to discuss the status of geologic mapping in the park, the associated bibliography, and the geologic issues in the park. The products to be derived from the scoping meeting are: (1) Digitized geologic maps covering the park; (2) An updated and verified bibliography; (3) Scoping summary (this report); and (4) A Geologic Resource Evaluation Report which brings together all of these products.

Dry Tortugas National Monument was established under Franklin D. Roosevelt's administration on January 4, 1935. On October 26, 1992, the monument was redesignated a national park. Dry Tortugas covers 64,701 acres and is located 112.9 km (70 miles) west of Key West. Over 99% of the park is under water. Seven keys, (Loggerhead, Garden, Bush, Long, Hospital, Middle, and East Keys) comprise the only subaerial exposures. The area covers a large portion of the outermost Florida Keys, a long tract of paleoreefs that stretch from Biscayne National Park to Dry Tortugas, some 193 km (120 miles). The park contains some of the most pristine marine habitat in the continental United States. Its isolated location attracts nesting birds and turtles to its shores. The strategic location also attracted military attention leading to the construction of the defensive Fort Jefferson on Garden Key.

Dry Tortugas National Park is covered by four quadrangles of interest (Dry Tortugas OE, Dry Tortugas OE E, Dry Tortugas OE S, and Dry Tortugas OE SE). However, additional coverage is required for underwater mapping in surrounding quadrangles. The Florida State Geologic Survey has digitized a geologic map covering the state at a small scale (~ 1:750,000). This map only displays one geologic unit for the park. Additional mapping at a smaller scale will be more helpful for park management.

Physiography

The Florida Keys are divided into three distinct sections: the upper. middle, and lower Keys (including Dry Tortugas). These divisions correspond to their orientation, morphology, water depth, and composition. The upper Keys are oriented almost north- south and buttress against the east- southeast winds. The middle Keys are oriented northeast- southwest and face directly into the east- southeast winds. The upper and middle Keys are composed of coralline limestone. The lower Keys are oriented nearly parallel to the winds and trend nearly east- west and are composed of oolite (preserved tidal- bar deposits?). Water depth is at a maximum in the middle Keys. As a result, the coral reef development is greatest in the shallower waters of the upper and lower Keys (Shinn et al., 1997).

East of Dry Tortugas is an area of extensive sand waves that are current- swept into crests as high as 3 m (9 ft), called the Quicksands. Sand accumulations are as thick as 12 m (40 ft). The reefs at Dry Tortugas are thick, as much as 17 m (55 ft). They form an elevated atoll- like rim. The sand islands are located around the atoll and are as much as 14 m (45 ft) thick (Loggerhead Key). The Holocene sediments at Dry Tortugas are mostly uncemented and the mixture of paleocorals and sands proved an unstable foundation for the construction of Fort Jefferson on Garden Key.

Geologic History of South Florida

Sediment cores (southwest of the Marquesas Keys, penetrated 4,500 m (15,000 ft) indicate that South Florida has been predominantly an area of carbonate accumulation since the Mesozoic.

Late Paleozoic Era – During the Mississippian, the landmass that would underlie the grand carbonate platform of Florida today was not attached to the North American Craton. It is speculated that it was attached to the northwest portion of the African continent (Condie and Sloan, 1998). However, marine carbonates were being deposited over large portions of the area atop a Paleozoic age crystalline basement high, the Peninsular Arch (Pollastro *et al.,* 2000). In the Pennsylvanian, a collision event, known as the Ouachita orogeny sutured the Florida landmass to the continent as Gondwanaland and North America collided eventually forming the supercontinent Pangaea. The land was still submerged and south Florida was located at the junction of the North American, South American, and African plates. Through the Permian, Pangaea remained intact (Condie and Sloan, 1998).

Early Mesozoic Era – No sooner had Pangaea formed than it began to break up. During the late Triassic, South and Central America and Africa began to rift away from North America. This established the long- standing passive margin of the eastern seaboard that persists today. The Florida and Cuba blocks detached from northwest Africa and the Gulf of Mexico opened (Condie and Sloan, 1998).

Accompanying the rifting of Pangaea was the widespread extrusion of volcanic rocks consistent with mantle plume upwelling due to crustal tension (Heatherington and Mueller, 1991). This continental rifting also opened the Atlantic Ocean basin.

Middle Mesozoic Era - Underlying the south Florida basin are igneous rhyolitic - basaltic rocks (Thomas et al., 1989). These rocks were subaerially exposed and eroded during the late Triassic to middle Jurassic. This caused the formation of redbeds locally. As the Atlantic Ocean continued to develop, deltaic and shallow marine sediments were deposited in the late Jurassic. Restriction of marine circulation at this time resulted in periodic accumulations of evaporites and marine carbonates (Cunningham, 2005). Deposition of Jurassic and Cretaceous sediments was controlled by the south- southeast plunging axis of the Peninsular Arch. Basal sediments onlap and pinch out against the arch (Pollastro *et al.,* 2000).

Late Mesozoic Era – As marine transgression proceeded during the early Cretaceous, the Florida Platform was the site of more widespread deposition of marine limestones and reefs. Further transgression and global warming during the Late Cretaceous established an open marine accumulation of carbonates over the entire Florida Peninsula.

Cenozoic Era – Cenozoic development of the Florida Platform included additional deposition of marine carbonates and deposition of siliciclastics (grains of silicate minerals such as quartz in lieu of carbonates) from northwestern highlands sources and long shore oceanic currents. Tertiary faulting occurred south of Florida as the Cuban block collided with the Antilles arc and carbonate accumulation continued in Florida (Condie and Sloan, 1998). In southern Florida, the open marine setting continued during the Paleocene as more restricted flow to the north resulted in deposits of mixed carbonates and evaporites. Eocene and Oligocene deposition is marked by shallow water carbonates. Intermittent with this deposition were subaerial exposures associated with local oceanic regressions.

Deposition in south Florida during the Miocene changed with the introduction of more widespread siliciclastics from a fluvio- deltaic system prograding down the peninsula. Phosphates and the carbonate ramp of the Arcadia Formation were deposited during the Miocene in south Florida. A Pliocene lowstand caused many of the previous deposits to be reworked and/or eroded. The Florida Keys area was active as a thick pile of sand that was being transported south to eventually form the Long Key Formation (Guertin et al., 1999; Cunningham, 2005). Continued carbonate accumulation in the Florida Keys during the Pliocene built the Stock Island Formation (Cunningham et al., 1998).

The Pleistocene era resulted in the conversion from siliciclastic deposition mixed with carbonate accumulation to more widespread carbonate sedimentation (Cunningham, 2005). Global sea- level changes during the intermittent ice ages of the Pleistocene controlled the rate and distribution of carbonate units. At 120 Ka, the last major sea level fall occurred as the reefs and the oolite facies were accumulating to become the Key Largo Limestone. Locally, the Pleistocene Key Largo Limestone (130 Ka) underlies the lower Keys including the Dry Tortugas. The Pleistocene section is south Florida is more than 61 m (200 ft) thick at Big Pine Key (Shinn *et al.*, 1997).

At 15- 16 Ka sea level began to rise rapidly and flood southern Florida around 7 or 6 Ka (Shinn *et al.,* 1997). Sea level has continued to rise. Holocene geologic activity in the Dry Tortugas area consists of the accumulation of coral reefs, sand deposits and carbonate muds. These deposits directly overlie the Pleistocene Key Largo Limestone. Reef distribution at Dry Tortugas is controlled by geologic and climatic factors such as the timing and rate of sea level rise, sediment facies, oceanic currents, and underlying bedrock (topography).

Stratigraphy

The USGS has installed monitoring wells at Garden Key of Dry Tortugas National Park. Cores from these wells reveal the upper 1 m (3 ft) to consist of sand and other anthropogenic debris. *Halimeda* is the most abundant biogenic sediment grain (Davis, Jr., and O'Neill, 1979). In the core, the next 15 m (50 ft) is Holocene limestone including head corals and numerous sand pockets, below the Holocene units is the Pleistocene Key Largo Limestone (fossilized patch reef complex and oolites) that underlies much of the South Florida Keys (Shinn *et al.*, 1979).

The Pleistocene section is of varying thickness and may contain as many as five separate facies units. In the lower keys (Big Pine Key), the section is more than 18 m (60 ft) thick. A Pleistocene coral facies (*Montastraea annularis*) underlies modern Holocene reefs. Pleistocene biogenic (*Halimeda*) underlies Holocene carbonate sands (Shinn *et al.*, 1997). The mixed stratigraphy from the Holocene caused the initial subsidence of Fort Jefferson. Differential subsidence continues to this day between the unconsolidated sand pockets and the limestones.

Marine units at Dry Tortugas include sandy shoals, lagoons, algal mats, patch reefs, bank barrier/fringing reefs, staghorn reefs, beach rock, hard bottom, and bare sand and rubble (Davis, 1979; Meeder, 1979; Ginsburg, 1979).

Significant Geologic Resource Management Issues in Dry Tortugas National Park

1. Coral reef framework rehabilitation and restoration

Due in part to its isolated location, Dry Tortugas protects pristine and unique coral communities with pinnacles, staghorn and elkhorn corals. Historically, the shallow shoals and reefs have caused numerous shipwrecks (Windjammer, Little Africa, Brick, etc). Today, the reefs and accompanying sea grass beds are under constant threat of degradation from vessel groundings and overuse. Private and public vessels as well as those from the local fishing industry (shrimpers) are all permitted safe harbor at the park and the high traffic in the area increases the likelihood of groundings and damage.

Given that coral growth rates are very slow, restoring a coral bank after a vessel grounding is more than just a matter of patching a hole, care must be given to the type of material used (i.e. concrete, fossil corals) and the encouragement of regrowth. To protect the environment, the banks must be restored before restoring damaged sea grass beds. Monitoring and research questions include: What is the best way to encourage growth on the reefs? What affect does loss of sea grass beds have on the marine environment? Should the number of permitted boat moorings be limited? How?

2. Sea level rise

Sea level rise is affecting all of South Florida. While slowing the rate of sea level rise is beyond the resources of the park, monitoring sea level change and evaluating/predicting impacts on the park's landscape is a valid management issue. The seven islands of Dry Tortugas are under constant threat of inundation by the sea. Several of the islands disappear seasonally due to rising seas including Middle Key. Bird Key has disappeared altogether. Given the low relief of the islands, this rise will destroy the bird and turtle nesting habitats protected at the park. The USGS and NOAA are working to determine the coastal vulnerability index (CVI) of the park.

Park management must continually balance 1) the aim to let natural processes take their course at Dry Tortugas, with 2) the preservation/restoration of the cultural resources present (Fort Jefferson and Loggerhead Key Lighthouse). Research and monitoring questions include: What is the best way to preserve the structure of Fort Jefferson from rising seas? Is there any way to save the subaerial habitat from rising seas? Will coral growth rates be able to change in response?

What is the local rate of sea level rise? Looking at the affects of storm surges, how will the islands respond to the rising water?

3. Island geomorphic processes and stability of Fort Jefferson

The very nature of the landscape at Dry Tortugas is one of change. Shifting sands continually alter the shape and profile of the islands. Sand erodes from one beach and is deposited elsewhere in the course of a single storm event (including two deposits in the fort's moat on the west and northeast sides). Focus also needs to be placed on understanding the sediment transport dynamics at the park. A relatively deep channel separated Garden Key and Bush Key until a large storm event joined them with a sand bridge. This sand bridge widens and recedes, but remains a persistent feature of the landscape. The anchorage at the park, to the south of Garden Key is being filled in. This affects access to the park as well as the safe harbor provided by the park. Dredging this area could have devastating effects on the local ecosystem.

Fort Jefferson is the largest of the 19^{th} century coastal fortifications in America. Construction began on Fort Jefferson in 1846, but was never finished due to uneven subsidence in the foundations on Garden Key. This subsidence was rapid at first and cracked the freshwater cisterns making it necessary to distill seawater or import water to the fort. Ongoing efforts are attempting to stabilize the fort and preserve this historical resource. Research and monitoring questions include: Should the channel between Garden and Bush Key be dredged to encourage circulation around the islands? Should the anchorage area be dredged? What effects would dredging have on the benthic/marine environments at the park? How will further stabilization of the fort affect the environment?

4. Benthic ecosystems

Benthic habitats comprise more than 99% of Dry Tortugas National Park. Environments can change within centimeters of topographic relief. Given the coverage of mapping at the park, normal surficial maps are not sufficient for complex management decisions at Dry Tortugas. An interdisciplinary approach to mapping is critical to producing a useful product for resource management. Anthropogenic, supratidal, intertidal, subtidal, and coastal features would all be helpful. This holistic ecosystem approach integrates biological, physical, cultural, and oceanographic variables.

USGS LIDAR surveys are adding detail to the elevation and geomorphic profiles at Dry Tortugas. These in addition to satellite imagery, multibeam mapping, bathymetry data, water quality and circulation, shoreline change data, pre/post storm comparisons, oceanographic data (waves, tides, currents, turbidity, temperature salinity, sediment transport patterns, coral larvae and other species distributions) are essential for resource management at Dry Tortugas National Park. Research and monitoring questions include: What is the minimum mapping unit relevant to resource management? Would banded maps of vulnerability patterns be useful? Could video be employed to monitor shoreline change at the park?

5. Groundwater flow dynamics

The interaction between groundwater flow and the overall marine ecological quality must be quantitatively determined at Dry Tortugas. Visitor uses as well as other boats are increasing the levels of certain substances in the water at the park. This is affecting corals, including the last stand of elkhorn coral near Bush and Long Keys). Nutrients from waste are causing algal blooms. The USGS has drilled a series of monitoring wells at the park, both inside and outside the fort to monitor water chemistry. A sand overflow into the fort's moat along the western wall from Hurricane Charlie in 2004 inundated one well.

Research and monitoring questions include: How many wells are necessary to model the hydrogeologic system at the park? What are the affects of the numerous boats moored in the anchorage of the park on water quality? How has the sediment transport affected groundwater flow patterns (i.e. the sand bridge between Garden and Bush Keys)?

6. Recreation and other use demands

In 2003, Dry Tortugas National Park hosted 74,576 recreation visits. These in addition to the boat moorings (public, private, and industry) are placing increasing demands on the limited resources and fragile ecosystems of the park. The most common visitor activities include snorkeling, the self- guided tour of the fort, camping, and swimming at the beach. Visitors access Dry Tortugas by Ferry (69%), seaplane (11%), commercial charter (10%), private sailboat (7%), private motor boat (2%), commercial dive boat (1%), and other (4%) (Ye and Littlejohn, 2003). These all have an impact on the parks benthic environments, viewshed, air and water quality, and noise levels.

Research and monitoring questions: Should the park restrict access to the islands? Would a guided boat tour decrease the environmental impact of visitation? Are visitors affecting sediment transport?

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Map of Dry Tortugas National Park